

Photogrammetry with an Unmanned Aerial System to Assess Body Condition and Growth of Blainville's Beaked Whales

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LONG-TERM GOALS

Understanding the population consequences of disturbance from operational activities will allow the US Navy to comply with take limits for protected marine mammals and to design effective mitigation. This is particularly relevant for beaked whales, which are known to be sensitive to anthropogenic noise, including navy sonar. Passive acoustics, controlled exposure experiments and telemetry studies indicate that Blainville's beaked whales (*Mesoplodon densirostris*, *Md*) move away from navy sonar sources and are displaced from their regular feeding habitat. Recent assessments of population age structure have led to a hypothesized population consequence of repeated disturbance by sonar at the US Navy's Atlantic Test and Evaluation Center (AUTC) in the Bahamas, with fewer calves and sub-adults contributing to lower overall abundance compared to a control population off Abaco Island (~170 km away).

Bioenergetics models support the plausibility of this hypothesis, suggesting that beaked whales require relatively high-quality habitat in order to meet their high energy requirements, and that regular displacement from preferred feeding habitats could potentially impact survival and reproduction through compromised body condition. This is of particular concern for lactating females with increased energetic demands, and could indeed result in lower reproductive success, reduced calf survival and negative population consequences. However, empirical data on female body condition and growth of calves is lacking, constraining a direct assessment of whether nutritional stress from disturbance is a realistic mechanism for explaining the apparent population responses.

We propose to use aerial photogrammetry to directly measure the body condition and growth of *Md*; specifically demonstrating the utility of the NOAA APH-22 marine hexacopter as an Unmanned Aerial System (UAS) for obtaining vertical images of whale lengths and width profiles. We anticipate this study will demonstrate the utility of photogrammetry using UAS for monitoring the body condition and growth of beaked whales, to facilitate an understanding of the effect of disturbance to individual health. This has direct relevance for future monitoring and understanding population-level effects of disturbance in navy operation areas (specifically *Md* at AUTC, but also other species on other ranges). The data collected in this study will also provide baseline data from a control population that is not regularly displaced by sonar.

OBJECTIVES

We propose to use the NOAA APH-22 marine hexacopter as an Unmanned Aerial System (UAS) to obtain vertical images of whale lengths and width profiles. This small, battery-powered platform is quiet, cost-effective and safe to operate from small boats, and can hover over animal groups. We will launch the hexacopter from a boat platform to fly short missions over beaked whales when they are sighted close-by at the surface, obtaining high resolution digital images from a height of ~30m. We will validate this system for beaked whales during a field trial in summer 2016 south of Great Abaco Island, northern Bahamas, where a photo-identification study over 18 years has demonstrated high site-fidelity of *Md*. Aerial images will be matched to photo-identifications to link measurements to whales with known histories, to obtain metrics for key age/sex classes:

- 1) Width profiles for adult females, specifically comparing those with (lactating) and without dependent young, to validate the ability to assess differences in body condition and detect pregnancy.
- 2) Lengths for dependent young of different ages, to validate the ability to measure growth.

APPROACH

Hexacopter Operations

We will obtain vertical images of beaked whales using a small remote hexacopter (APH-22, Aerial Imaging Solutions) that NOAA/SWFSC has developed collaboratively for marine applications. This small (4.5lbs, 32" wingspan) platform is a vertical take-off and landing (VTOL) UAS, making it easy and safe to operate from small boats and can hover over animal groups during photographic operations. The aircraft is quiet, powered by a 4-cell lithium polymer battery that drives six brushless electric motors. The aircraft's attitude, altitude and heading are stabilized by an electronic control system that incorporates three gyros, three accelerometers, a magnetic compass, a barometric pressure sensor, a GPS receiver, and eight microprocessors; it is extremely stable in flight, and easily maneuvered by an experienced pilot using radio controls. Images will be collected using a micro 4/3 camera (Olympus E-PM2, 16MP RAW files) with a 25mm f1.8 lens, mounted on the hexacopter to be downward-pointing. The use of a mirrorless camera minimizes the payload and enables flight durations of up to 20 minutes.

For studies of beaked whales, we aim to launch the hexacopter from a small boat (6.8m RHIB) when they are sighted close-by at the surface. Flights of 15-20 minutes are intended to encompass at least two surfacing bouts between shallow dives when *Md* are not on a foraging dive (mean shallow dive duration of ~9 minutes for *Md*; Tyack et al. 2006), providing opportunity for repeated photographic approaches. An experienced pilot (JWD) will operate the hexacopter using remote controls at a height

of ~100ft, aided by live video output from the hexacopter that will be monitored on a portable ground unit in real-time by a co-pilot (HOF) to facilitate targeting. Initial targeting to position the whales within the camera's field of view will be facilitated by the high mobility of the hexacopter (max speed = 15m/s or 30kts) and the experience of the operators. Once located in the image, we expect beaked whales will remain visible from the air when they are submerged during shallow dives allowing the co-pilot to direct the hexacopter to stay overhead until they resurface. Upon surfacing, the pilot will remotely trigger the camera to record high-resolution still photographs (RAW format) at one second intervals to maximize the chance of obtaining "flat" images for unbiased photogrammetry measurements. Multiple batteries for the hexacopter will be carried on the RHIB to enable repeated flights during optimal weather windows. The RHIB will be repositioned during flights to maintain a consistent contact distance (between 300 and 750ft) of the whales, to facilitate targeting and allow lateral identification photographs to be obtained.

Linking to known individual whales

A further benefit to conducting this feasibility study off south Abaco is the ability to obtain photogrammetry images of whales with known histories. Since 1997 BMMRO has photo-identified 167 different individual *Mds* in this sheltered coastal study site, with notable site fidelity of adult females ($n = 57$, average days seen = 6, max = 41). Aerial images and measurements will be assigned to specific individuals based on the pattern of healed wounds from the bites of cookie-cutter sharks that should be readily distinctive from the air and matchable to BMMRO's catalog of known whales.

To facilitate matches to known beaked whales, we will also collect lateral photo-identifications from the boat of all groups that we image from the air, and use group photography from both platforms to record the spacing of the individuals. Additionally, Blainville's beaked whales can be readily assigned to age/sex classes from photographs of dentition and scarring (Claridge 2013), enabling us to link measurements to classes if there is no long-term sighting history from a particular whale.

Key measurements

We expect to obtain high resolution images of beaked whale groups, comprising whales of differing lengths and shapes, and we will take measurements from these images to infer growth and body condition. By linking measurements to individuals with known histories, ages and sex classes, we will seek validation of our measurements and also learn about key variation in morphometrics. Notably, these will include width profiles for adult females in varying reproductive states to validate the ability to assess differences in body condition and detect pregnancies, and lengths for dependent whales of different ages to validate the ability to measure growth of young whales.

Lactation imposes high energetic demands for female cetaceans (New et al. 2013) and aerial photogrammetry has demonstrated that their body condition can be compromised in the early months of lactation when they may have to rely on endogenous nutrient reserves to support the increased energy expenditure. Notably, it has been shown that thoracic, abdominal and caudal body width of right whales thinned significantly during the initial months of lactation, while their calves' widths-to-length ratios increased (Miller et al. 2012). Similarly, Durban et al. (2009) found that a newborn calf in its first year of life had the largest head width-to-length ratio in a photogrammetry sample of killer whales, and its lactating mother had the thinnest. We therefore expect the width profiles for adult female *Mds* to vary depending on reproductive condition, and will specifically compare those with (lactating) and without dependent young to examine our resolution for detecting these differences. The extent to which lactating females need to rely on endogenous reserves clearly depends on food availability and feeding success, and therefore measures of body condition can provide an integrated

assessment of these key life functions. As such, data on differences between lactating and non-lactating females will also provide an index of feeding success and nutritional status in this population, which will serve as a baseline for comparison to other *Md* populations (e.g. at AUTECH).

Widths will be expressed as a proportion of length, to control for individual differences in size. We will specifically compare the width of each whale at 5% intervals along the body axis in order to identify the most sensitive (variable) measurement sites for this species. In addition to nutritional state, these full width profiles are expected to also allow identification of whales in the latter stages of pregnancy: studies of killer whales have shown that pregnant females (confirmed with new calves in the field season subsequent to the photogrammetry effort) had anomalous shape profiles. Validating our ability to detect pregnancies from aerial photographs will further allow us to monitor the covariates underlying reproductive success. Specifically, it will allow us to identify and enumerate terminated pregnancies or mortalities of newborns prior to their detection, to facilitate an understanding of beaked whale age structure.

For absolute length, size in pixels will be converted using a measure of scale (scale= altitude/lens focal length), with altitude measured onboard the hexacopter using a pressure altimeter and a digital GPS that receives corrected data (e.g. Fearnbach et al. 2011). Finer scale resolution of length differences will also be examined by measuring dependent whales of different ages, to validate our ability to assess growth of young whales. Resighting histories of whales will allow us to estimate their relative ages to compare growth of young whales and assess growth relative to the body condition of their mothers.

WORK COMPLETED

Field work is scheduled from June 6th to June 28th, 2016.

RESULTS

Not yet available.

IMPACT/APPLICATIONS

Understanding the population consequences of disturbance from operational activities will allow the US Navy to comply with take limits for protected marine mammals and design effective mitigation. This is particularly relevant for beaked whales, which are known to be sensitive to anthropogenic noise, including navy sonar. Towards this aim, the US Navy has supported the development of the Population Consequences Of Disturbance (PCOD) analysis framework, designed to trace the effects of disturbance through life functions to population status. However, key steps of this model can be hard to parameterize and thus understand, particularly for cryptic species like beaked whales.

Life functions such as feeding success can be particularly hard to observe, constraining our understanding of the integrated consequences of changes in body condition and growth on key vital rates. To date, these constraints have prevented a direct assessment of whether nutritional stress from disturbance is a realistic mechanism for population-level responses. Here we aim to demonstrate the utility of photogrammetry as a tool for directly measuring body condition and growth of individually-recognizable whales, facilitating an understanding of the effect of disturbance on individual health. This has direct relevance for future monitoring and understanding of the population-level effects of

disturbance in navy operation areas; not just *Md* at AUTECH, but also other marine mammal species on other ranges (e.g. Cuvier's beaked whales, *Ziphius cavirostris*, at the Southern California Offshore Range; short-finned pilot whales, *Globicephala macrorhynchus*, at the Jacksonville Range Complex). To begin this monitoring, this study also aims to collect baseline data from a control population of *Md* off South Abaco that is not regularly displaced by sonar, providing a valuable comparison to future data that may be collected from whales that use the nearby AUTECH range.

As a monitoring tool, this study will demonstrate that the NOAA APH-22 marine hexacopter is a cost-effective, safe and non-invasive UAS platform for collecting high-resolution photogrammetry images. Notably, the UAS can be deployed from small boat platforms, allowing photogrammetry to be efficiently conducted as part of ongoing boat-based data collection efforts.

RELATED PROJECTS

Monitoring beaked whale movements during the Submarine Commanders Course using satellite telemetry

This project is a collaborative project between the Bahamas Marine Mammal Research Organisation, NOAA Southwest Fisheries Science Center and the Naval Undersea Warfare Center (David Moretti). Satellite telemetry is being used to monitor the movements and diving behavior of beaked whales and other odontocete cetacean species on the US Navy's Atlantic Undersea Test and Evaluation Center (AUTECH) range before, during and after sonar exercises in which multiple ships are using their tactical sonars. Field work during this project is providing opportunity to collect biopsy samples and photo-identification data at AUTECH. This project has been supported by the US Department of Defense (NACFAC - Living Marine Resources Program).

REFERENCES

- Andrews, R. D., Pitman, R. L., and Ballance, L. T. 2008. Satellite tracking reveals distinct movement patterns for Type B and Type C killer whales in the southern Ross Sea, Antarctica. *Polar Biology* 31:1461-1468.
- Claridge, D. E. 2013. Population Ecology of Blainville's beaked whales (*Mesoplodon densirostris*). PhD in Biology. University of St Andrews, Scotland.
- Durban, J., Fearnbach, H., Ellifrit, D., and Balcomb, K.C. 2009. Size and body condition of southern resident killer whales. Contract report to the Northwest Regional Office, National Marine Fisheries Service, Order number AB133F08SE4742, Requisition Number NFFP5000-8-43300.
- Fearnbach, H., Durban, J.W. Ellifrit, D.K. and Balcomb, K.C. 2011. Size and long-term growth trends of endangered fish-eating killer whales. *Endangered Species Research* 13: 173-180.
- Goebel M.E., Perryman W.L., Hinke, J.T., Krause, D.J., Hann N.A. Steve Gardner S. and LeRoi, D.J. In press. A Small Unmanned Aerial System for Estimating Abundance and Size of Antarctic Predators. *Polar Biology*.
- Johnson, D.S., London, J.M., Lea, M.A. and Durban, J.W. 2008. Continuous-time correlated random walk models for animal movement data. *Ecology* 89: 1208-1215.
- McCarthy, E., Moretti, D., Thomas, L., DiMarzio, N., Morrissey, R., Jarvis, S., and Dilley, A. 2011. Changes in spatial and temporal distribution and vocal behavior of Blainville's beaked whales

- (*Mesoplodon densirostris*) during multiship exercises with mid-frequency sonar. *Marine Mammal Science* 27 E206-E226.
- Mead, J. G. 1989. Beaked whales of the genus *Mesoplodon*. *Handbook of Marine Mammals* 349-430.
- Miller, C. A., Best, P. B., Perryman, W. L., Baumgartner, M. F., & Moore, M. J. 2012. Body shape changes associated with reproductive status, nutritive condition and growth in right whales *Eubalaena glacialis* and *E. australis*. *Marine Ecology Progress Series* 459: 135-156.
- Moretti, D., Thomas, L., Marques, T., Harwood, J., Dilley, A., Neales, B., and Morrissey, R. 2014. A Risk Function for Behavioral Disruption of Blainville's Beaked Whales (*Mesoplodon densirostris*) from Mid-Frequency Active Sonar. *PloS one* 9 e85064.
- National Research Council. (2005). *Marine Mammal Populations and Ocean Noise: Determining when noise causes biologically significant effects*. The National Academy Press. Washington D.C.
- New, L.F., Moretti, D.J., Hooker S.K., Costa D.P., Daniel P. Costa, and Simmons, S.E. 2013. Using energetic models to investigate the survival and reproduction of beaked whales (family *Ziphiidae*). *PloS One* 8: e68725.
- Perryman, W.L., and Lynn, M.S. 2002. Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. *Journal of Cetacean Research and Management* 4: 155-164.
- Schorr, G. S., Falcone, E. A., Moretti, D. J., & Andrews, R. D. 2014. First long-term behavioral records from Cuvier's beaked whales (*Ziphius cavirostris*) reveal record-breaking dives. *PloS One* 9: e92633.
- Tyack, P. L., Johnson, M., Soto, N. A., Sturlese, A., & Madsen, P. T. 2006. Extreme diving of beaked whales. *Journal of Experimental Biology*, 209: 4238-4253.
- Tyack, P.L., Zimmer, W.M., Moretti, D., Southall, B.L, Claridge, D.E., Durban, J.W., Clark, C.C. et al. 2011. Beaked whales respond to simulated and actual navy sonar. *PLoS One* 6: e17009